Рост наноструктур по механизму Фольмера–Вебера
Growth of nanostructures by Volmer–Weber mechanism

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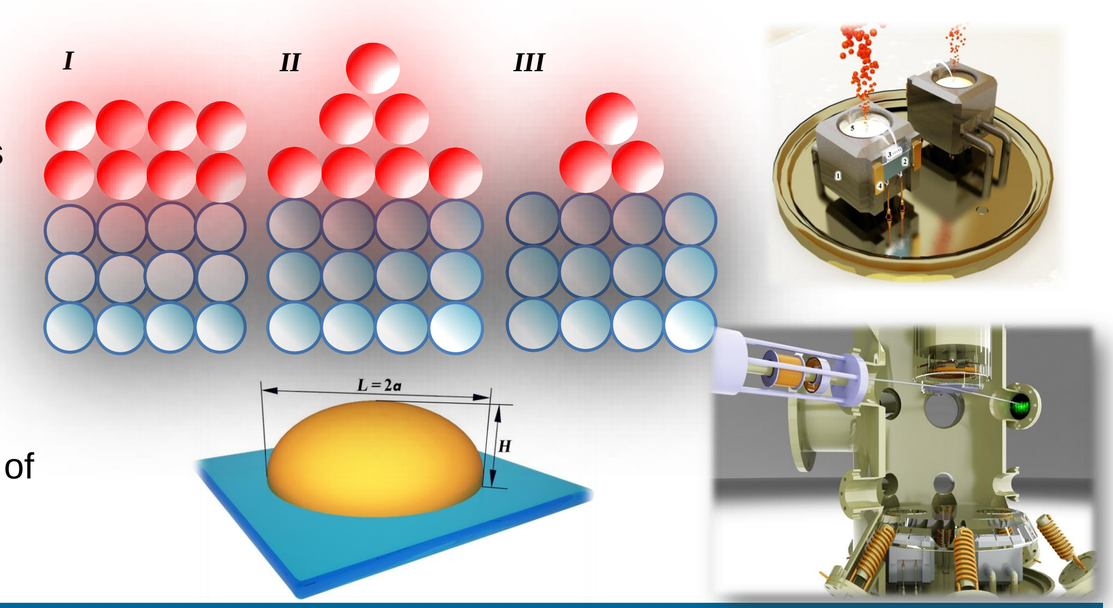
Mechanisms of Epitaxial Growth

- **Frank-van der Merwe** growth mode is realized for **homoepitaxial** systems
- **F–M** growth mode is also typical for systems with close values of lattice mismatch ε_0
- **F–M** growth mode may be used for creation of 2D crystals for topological electronics

- **Stranski-Krastanow** growth mode is typical for **Ge/Si** and **InAs/GaAs** systems
- 1st stage: **layer-by-layer** (**2D**) growth
- 2nd stage: nucleation of **3D hut-clusters** caused by relaxation of elastic strain
- 3rd stage: emergence of two separate shapes – **hut- and dome-clusters**
- 4th stage: **interaction between islands** and disappearance of small islands in favor of bigger islands



Volmer–Weber Growth

- **Volmer-Weber** growth mode is realized for **Ge/SiO_2/Si** and **$A^{III}B^{V}$/Si** systems
- Nucleation of **3D clusters** proceeds on top of the substrate without formation of the wetting layer
- Typical for systems with high values of lattice mismatch ε_0

- Quantum dot shape: pyramid with **circle base**
- Expression for the **free energy** of island formation:

$$\Delta F = \Delta F_{elas} + \Delta F_{surf} + \Delta F_{attr} + \Delta F_{inter}$$

- Growth mechanism: **diffusion of adatoms** from the wetting layer into an island
- Taking into account interaction between islands

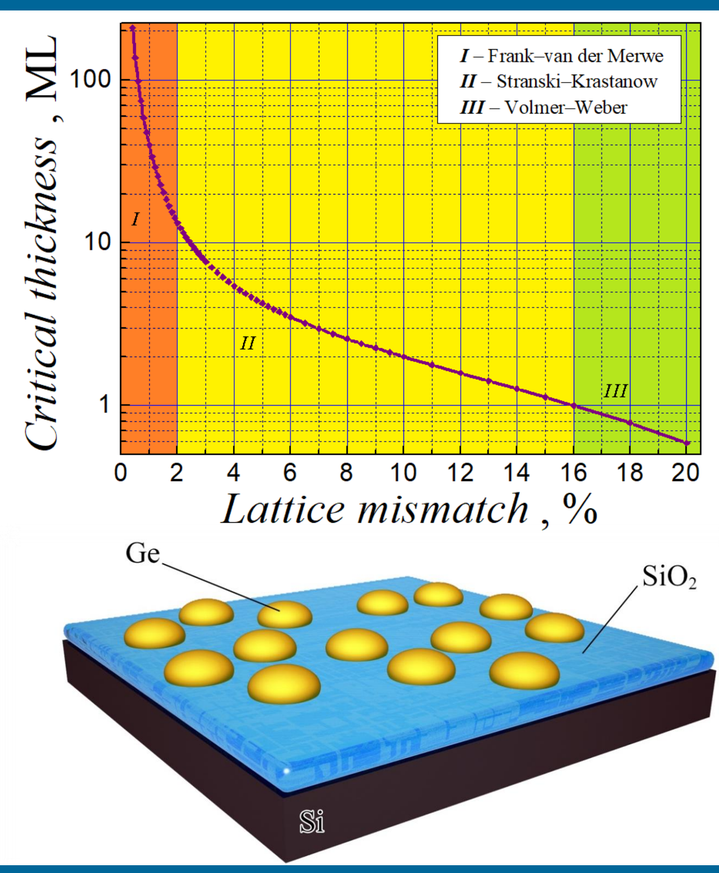


Figure 1. Dependency of the critical number of atoms and the critical thickness of transition from 2D to 3D growth on lattice mismatch for the growth temperature ***T* = 450 °C**.

Inset: Formation of germanium islands on oxidized silicon substrate and model geometry of island grown by Volmer–Weber mechanism.

Evolution of Epitaxial Quantum Dots Formed by Volmer–Weber Mechanism

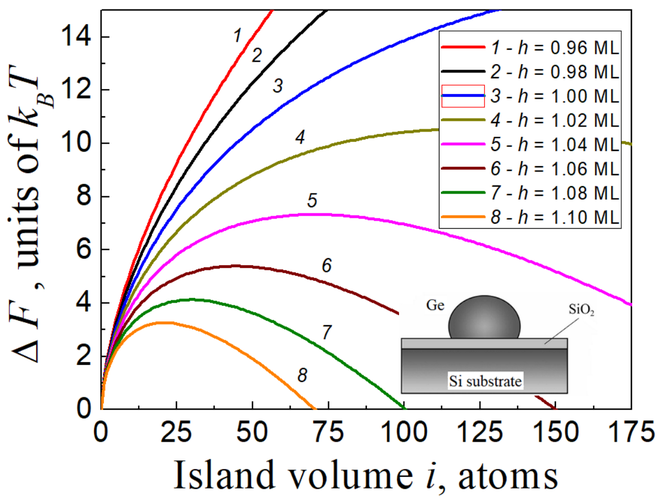


Figure 2. Change in free energy in Ge/SiO_2/Si system for the thicknesses of deposited germanium h = 0.96–1.1 ML at the temperature ***T* = 400 °C**.

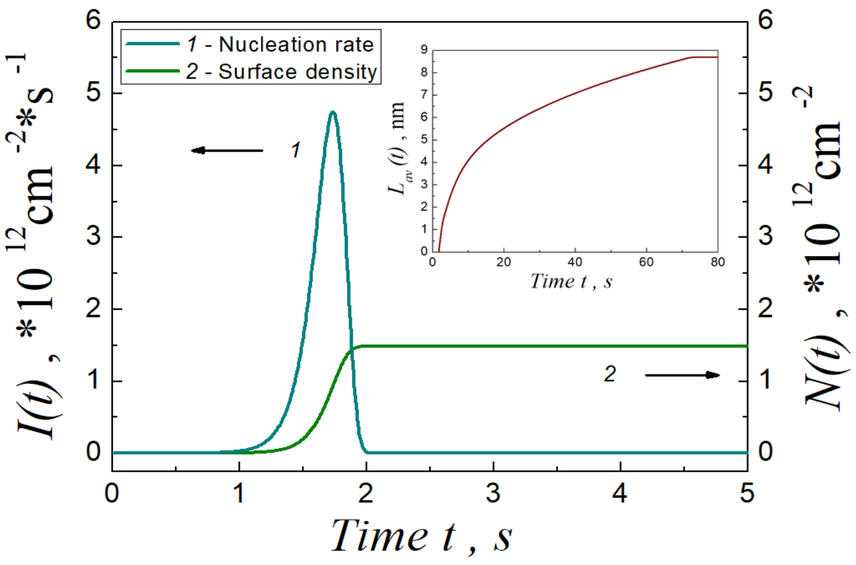


Figure 3. Time dependencies of islands nucleation rate I (*1*), surface density N (*2*) and average size (inset) of quantum dots for the growth temperature ***T* = 400 °C** and germanium deposition rate ***V* = 0.07 ML/s**.

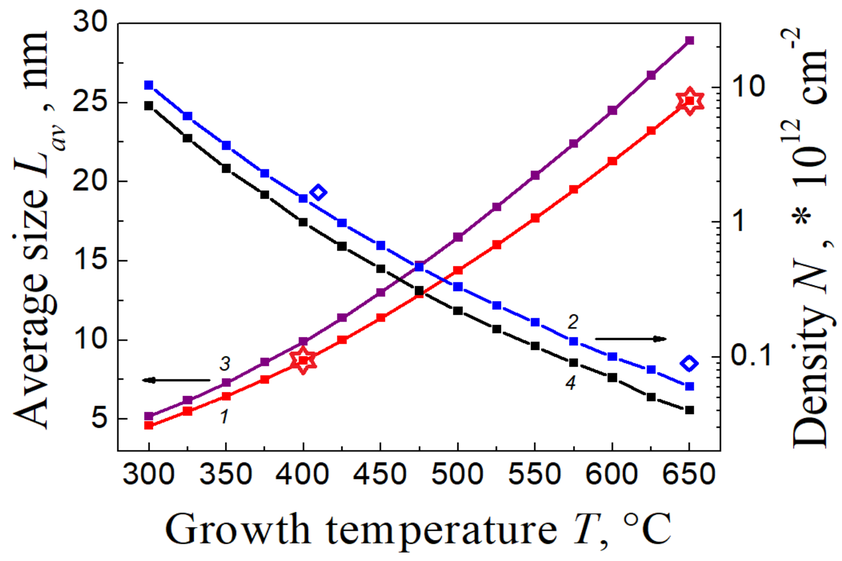


Figure 4. Dependencies of the mean lateral size (*1*, *3*) and surface density (*2*, *4*) of Volmer-Weber islands on growth temperature for the deposition rates of Ge ***V* = 0.07 ML/s** (*1*, *2*) and ***V* = 0.05 ML/s** (*3*, *4*). Symbols – experiment.

Conclusions

- As a result, in this work fundamental **peculiarities** of epitaxial formation and growth of quantum dots by Volmer–Weber, Stranski–Krastanow and Frank–van der Merwe **growth mechanisms** are considered. **Generalized kinetic model** of nucleation and growth of 2D layers and 3D islands by all three mechanisms **is proposed**. Dependencies of the parameters of grown structures on the synthesis conditions are obtained.
- The developed **model allows** one to evaluate not only equilibrium values of system with quantum dots (their average size and surface density), but also principally **non-equilibrium parameters** such as islands nucleation rate, size distribution function and its **time evolution**. The results of numerical simulations of Volmer–Weber growth for the Ge/SiO_2/Si system show **good agreement with experimental data**.
- Ways to control the properties of obtained 2D and 0D nanostructures for **nanoelectronics and photonics** are proposed with the help of the model.